PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Life History And Survival Of Fall Chinook Salmon In Columbia River Basin

BPA project number: 9102900
Contract renewal date (mm/yyyy): 6/1999 ☐ **Multiple actions?**

Business name of agency, institution or organization requesting funding
U. S. Geological Survey - Biological Resources Division

Business acronym (if appropriate) USGS

Proposal contact person or principal investigator:

Name	Dennis W. Rondorf
Mailing Address	5501A Cook-Underwood Rd.
City, ST Zip	Cook, WA 98605
Phone	(509) 538-2299
Fax	(509) 538-2843
Email address	dennis_rondorf@usgs.gov

NPPC Program Measure Number(s) which this project addresses
7.5B.3, 7.3B.5, 7.5B.1, 2.2A, 5.7, 5.0F, 7.1A.1, 7.6A.2

FWS/NMFS Biological Opinion Number(s) which this project addresses
NMFS BO RPA 13f: "The BPA shall evaluate juvenile survival during downstream migration and desired level of flow augmentation."

Other planning document references
Wy Kan Ush Me Wa Kush Wi Artificial Production Actions for the Snake River Mainstem Action 8: Monitor and evaluate all artificial production actions. Snake River Salmon Recovery Plan measures 4.1.2 (supplementation), 2.1.d.3 (survival and flow augmentation), and 2.8.b.2. (predator and salmonid interactions).

Short description
Facilitate implementation of federal and tribal fall chinook salmon recovery plans by monitoring and evaluating post-release attributes and survival of natural and hatchery juvenile fall chinook in the Snake River and Hanford Reach of the Columbia River.

Target species
Fall chinook salmon

Section 2. Sorting and evaluation

Subbasin
Snake River, Columbia River

Evaluation Process Sort

CBFWA caucus	Special evaluation process	ISRP project type
Mark one or more caucus	If your project fits either of these processes, mark one or both	Mark one or more categories
☒ Anadromous fish ☐ Resident fish ☐ Wildlife	☐ Multi-year (milestone-based evaluation) ☐ Watershed project evaluation	☐ Watershed councils/model watersheds ☐ Information dissemination ☐ Operation & maintenance ☐ New construction ☒ Research & monitoring ☐ Implementation & management ☐ Wildlife habitat acquisitions

Section 3. Relationships to other Bonneville projects

Umbrella / sub-proposal relationships. List umbrella project first.

Project #	Project title/description
20541	Snake River fall chinook salmon studies/Umbrella Proposal
9102900	Life history and survival of fall chinook salmon in the Columbia R. basin
9403400	Assessing summer and fall chinook restoration in the Snake River
9801003	Monitor and evaluate spawning distribution of Snake R. fall chinook salmon
9801004	M&E of yearling Snake R. fall chinook released upstream of L. Granite Dam
9801005	Pittsburg Ldg., Capt. John Rapid, & Big Canyon fall chinook acclimation fac

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship
9302900	Survival estimates for juvenile salmonids through lower Snake River	Collaborative effort to estimate survival of hatchery and natural fall chinook in the Snake River
9403400	Assessing summer/fall chinook salmon restoration in the Snake River basin	Collaborative effort to estimate survival of hatchery and natural fall chinook in the Snake and Clearwater rivers
9701400	Hanford Reach fall chinook stranding evaluation	Coordinating survival estimation, and cost sharing of a bathymetric survey of Hanford Reach
9800401	Assess impacts of development and operation of Columbia R. hydroelectic sys	Mainstem habitat GIS work complements our juvenile rearing habitat assessments

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?
1992	Refined field technique for PIT tagging juvenile fall chinook salmon	PIT tagging allowed us to accomplish a myriad of study objectives
1992	Minimum Snake River flows established for spawning, incubation, and emergence	Minimum flows were based on our spawning habitat survey efforts
1993	Development of underwater video system for counting fall chinook redds in deep water	This system improved redd count accuracy while minimizing costs.

1993	Detailed habitat maps produced for a major spawning location in the Snake River.	Description of the physical attributes of fall chinook redds and spawning locations.
1993	1991 Annual Project Report to BPA	
1994	Completed juvenile marking study at McNary Dam	Defined the relationship between flow, fish size, and travel time, and described physiological development of rearing parr and migrating smolts
1994	1992 and 1993 Annual Project Reports to BPA	
1995	Completed assessment of variables that define juvenile fall chinook rearing habitat	Defined habitats that should be suitable for fall chinook production.
1996	Annual fall chinook redd counts in the Snake River have been made for 1991 through 1996 by this project.	This information has been for monitoring fall chinook population status and by NMFS to predict outmigration run sizes
1996	1994 Annual Project Report to BPA	
1997	1995 Annual Project Report to BPA	
1997	Summary of three years of radio telemetry data describing fall chinook migratory behavior.	Migration rates are not constant as assumed using PIT tags; delay in forebays is a problem
1998	Run timing forecasts for Snake River fall chinook have been provided to TMT from 1991 through 1998	This information has been used to time summer flow augmentation
1998	1996-97 Annual Project Report to BPA	

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Determine the effects rearing area, flow, and temperature on natural fall chinook salmon survival and migration timing to the tail race of Lower Granite Dam.	a	Capture and PIT tag natural fall chinook salmon rearing in different areas of Hells Canyon.
		b	Provide annual run-timing estimates for juvenile Snake River fall chinook for the Smolt Monitoring Program and Fish Passage Advisory Committee and summer flow augmentation decisions.
		c	Test for differences in detection patterns at Lower Granite Dam of fish tagged in different rearing areas.
		d	Determine if survival of release groups is related to rearing area, flow, temperature, and travel time.
2	Investigate the occurrence of yearling emigration (i.e., residualism) in Snake River fall chinook salmon.	a	Determine the prevalence of subyearling holdover using PIT tag detection data.
		b	Correlate the prevalence of holdover with environmental and genetic data.
		c	Determine the feasibility of estimating the origin of holdover fish using genetic and scale pattern data.
3	Evaluate the effect of fish size at release and environmental attributes on survival of Lyons Ferry subyearling fall chinook	a	Obtain and release sufficient numbers of hatchery fall chinook salmon to determine the effects of size at release on survival

	salmon.		through lower Snake River dams.
		b	Estimate survival of each hatchery release group using the SURPH model (Smith et al. 1994)
		c	Use multivariate statistics and analysis of variance techniques to determine if differences in survival are related to fish size, temperature, flow, and travel times.
4	Determine habitat use and migratory behavior of hatchery and natural fall chinook salmon in the Snake River.	a	Determine post-release dispersal patterns of hatchery fish in Hells Canyon.
		b	Describe post-release habitat use by hatchery fish to determine the extent of hatchery-wild overlap in nearshore rearing areas.
		c	Use radio telemetry to describe the migratory behavior and thermal history of active migrants in the lower Snake River.
5	Assess the relationship between growth rate and predation risk for hatchery treatment groups and natural fall chinook salmon.	a	Modify and use an existing chinook salmon bioenergetics model to predict food consumption and growth of hatchery and wild fish in nearshore rearing areas.
		b	Determine the extent and size selectivity of predation by smallmouth bass on hatchery and wild subyearling fall chinook in the Hells Canyon Reach.
		c	Use an individual-based modeling approach (Jager et al. 1993) to synthesize predation risk and growth advantage as it relates to survival, supplementation scenarios, and environmental conditions.
6	Determine the effect of seaward migration timing on natural Hanford Reach fall chinook salmon survival to the McNary and John Day dam tailraces, and compare findings to those for the Snake River from Objective 1.	a	Capture and PIT tag natural fall chinook salmon rearing in the Hanford Reach.
		b	Test for differences in seaward migration timing among weekly releases.
		c	Test for differences in survival to the tailrace of McNary and John Day dams among the weekly releases.
		d	Determine the relation between survival and flow, temperature, and turbidity.
		e	Test for differences in early life history (i.e., emergence timing, growth, and migration timing) and survival between Snake River and Hanford Reach fish.
7	Determine the effects of flow fluctuations on the quantity and quality of juvenile fall chinook rearing habitat in the Hanford and Hells Canyon reaches for a comparison of healthy and depressed stocks.	a	Produce a bathymetric map of rearing areas in the Hanford Reach and Hells Canyon.

		b	Collect water velocity information for surveyed areas for use as a criterion to define quality rearing habitat, and for flow modeling.
		c	Choose a two-dimensional flow model that will predict water surface elevations given river discharge.
		d	Synthesize the above information with variables that define quality juvenile fall chinook rearing habitats into a predictive model.

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
1	4/1991	5/2002	Early life history survival and run timing	Annual run timing estimates	20.00%
2	8/1995	7/1997	Quantify occurrence of residualism	Complete except for analysis	2.00%
3	5/1995	8/1998	Determine effect of fish size on survival	Complete except for analysis	3.00%
4	5/1995	5/2001	Determine effects of environmental variables and behavior on survival		5.00%
5	5/1995	5/2001	Determine effects of growth and predation of survival	Complete except for analysis	5.00%
6	6/2000	5/2002	Estimate survival of Hanford Reach fall chinook		35.00%
7	6/2000	5/2002	Effects of flow fluctuations on fall chinook rearing habitat		30.00%
				Total	100.00%

Schedule constraints

A LIDAR habitat survey in the Hanford Reach is potentially limited by contractor availability

Completion date

2001

Section 5. Budget

FY99 project budget (BPA obligated): $900,000

FY2000 budget by line item

Item	Note	% of total	FY2000
Personnel		%41	335,600
Fringe benefits		%12	102,800
Supplies, materials, non-expendable property		%3	31,500

Operations & maintenance			
Capital acquisitions or improvements (e.g. land, buildings, major equip.)			
NEPA costs			
Construction-related support			
PIT tags	# of tags: 9250	%3	26,825
Travel		%2	23,700
Indirect costs	Administrative overhead	%24	199,000
Subcontractor	U.S. Army COE - LIDAR survey	%6	50,000
Other	Vehicle leasing and boat operation and maintenance	%3	30,100
		TOTAL BPA FY2000 BUDGET REQUEST	$799,525

Cost sharing

Organization	Item or service provided	% total project cost (incl. BPA)	Amount ($)
		Total project cost (including BPA portion)	$799,525

Outyear costs

	FY2001	FY02	FY03	FY04
Total budget	$799,525			

Section 6. References

Watershed?	Reference
☐	Bevan, D. and several co-authors. 1994. Snake River Salmon Recovery Team: Final Recommendations to the National Marine Fisheries Service.
☐	Bugert, R.M., G.W. Mendel, and P.R. Seidel. 1997. Adult returns of subyearling and yearling fall chinook salmon released from a Snake River hatchery or transported downstream. North American Journal of Fisheries Management 14:638-651.
☐	Burnham, K.P., D.R. Anderson, G.C. White, C. Brownie, and K.H. Pollack. 1987. Design and analysis methods for fish survival experiments based on release-recapture. American Fisheries Society Monograph 5, Bethesda, Maryland.
☐	Connor, W.P., H.L. Burge, and D.H. Bennett. 1998. Detection of PIT-tagged subyearling chinook salmon at a Snake River dam: Implications for summer flow augmentation. North American Journal of Fisheries Management 18:530-536.
☐	Dauble, D.D., and D.G. Watson. 1997. Status of fall chinook salmon populations in the mid-Columbia River, 1948-1992. North American Journal of Fisheries Management 17:283-300.
☐	Hansel, H.C., S.D. Duke, P.T Lofy, and G.A. Gray. 1988. Use of diagnostic bones to identify and estimate original lengths of ingested prey fishes. Transactions of the American Fisheries Society 117:55-62.
☐	Huntington, C., W. Nehlsen, and J. Bowers. 1996. A survey of healthy native stocks of anadromous salmonids in the Pacific Northwest and California. Fisheries 21(3):6-14.

☐	Irving, J.S., and T.C. Bjornn. 1981. Status of Snake River fall chinoook salmon in relation to the Endangered Species Act. Prepared for the U.S. Fish and Wildlife Service, Portland, Oregon.
☐	Jager, H.I., and seven coauthors. 1993. An individual-based model for smallmouth bass reproduction and young-of-year dynamics in streams. Rivers 4:91-113.
☐	Lavoy, L. 1995. Stock composition of fall chinook salmon at Lower Granite Dam in 1994. Washington Department of Fish and Wildlife, Anadromous Fish Division - Columbia River, Progress Report 95-6, Battle Ground, Washington.
☐	NMFS (National Marine Fisheries Service). 1992. Threatened status for Snake River spring/summer chinook salmon, threatened status for Snake River fall chinook salmon. Final rule, April 22, 1992. Federal Register, Vol. 57, No. 78.
☐	NMFS (National Marine Fisheries Service). 1995. Proposed recovery plan for Snake River salmon. U.S. Department of Commerce, National Oceanographic and Atmospheric Administration. Portland, Oregon.
☐	Roseberg, R., H.L. Burge, W. Miller, and D. Diggs. 1992. A review of coded-wire tagged fish released from Dworshak, Kosskia, and Hagerman National Fish Hatcheries, 1976-1990. U.S. Fish and Wildlife Service, Idaho Fishery Resource Office, Ahsahka, Idaho
☐	Shively, R.S., T.P. Poe, and S.T. Sauter. 1996. Feeding response by northern squawfish to a hatchery release of juvenile salmonids in the Clearwater River, Idaho. Transactions of the American Fisheries Society 125:230-236.
☐	Smith, S.G., J.R. Skalski, J.W. Schlechte, A. Hoffman, and V. Cassen. 1994. Statistical survival analysis of fish and wildlife tagging studies. SURPH.1 Manual. Center for Quantitative Science, University of Washington, Seattle, Washington.
☐	Smith, S.G., W.D. Muir, E.E. Hockersmith, and W.P. Connor. 1996. Passage survival of natural and hatchery subyearling fall chinook salmon to Lower Granite, Little Goose, and Lower Monumental dams. Chapter 1 in Annual Report to BPA and COE.
☐	Stewart, D.J., and M. Ibarra. 1991. Predation and production by salmonine fishes in Lake Michigan, 1978-88. Canadian Journal of Fisheries and Aquatic Sciences 48:909-922.
☐	Tabor, R.A., R.S. Shively, and T.P. Poe. 1993. Predation on juvenile salmonids by smallmouth bass and northern squawfish in the Columbia River near Richland, Washington. North American Journal of Fisheries Management 13:831-838.
☐	USFWS (U.S. Fish and Wildlife Service) 1988. Endangered Species Act of 1973 as ammended through the 100th Congress. United States Department of the Interior, Washington, D.C.
☐	Waples, R.S., R.P. Jones, B.R. Beckman, and G.A. Swan. 1991. Status review for Snake River fall chinook salmon. U.S. Department of Commerce, National Oceanographic and Atmospheric Administration Technical Memorandum NMFS F/NWC-201. Portland, Oregon.
☐	Winton, J., and R. Hilborn. 1994. Lessons from supplementation of chinook salmon in British Columbia. North American Journal of Fisheries Management 14:1-13.

PART II - NARRATIVE

Section 7. Abstract

The goal of this project is to provide information that will aid in the recovery of Snake River fall chinook salmon populations, and to further our understanding of the mechanisms that make the Hanford Reach fall chinook population successful. This will be accomplished by providing both real-time data and published, peer-reviewed information for adaptive management. In brief, our objectives include: 1) relating early life history of natural fall chinook salmon to smolt survival; 2) investigating residualism (i.e., holdover or yearling emigration); 3) evaluating fish size at release and environemental attributes on the survival of hatchery fall chinook released for supplementation; 4) defining habitat use of hatchery and natural fall

chinook, and migratory behavior; 5) examining growth, predation, and migratory behavior as mechanisms of survival; 6) estimating the survival of Hanford Reach juvenile fall chinook salmon to McNary and John Day dams; and 7) determining the effects of flow fluctuations on rearing habitat in the Hanford Reach and Hells Canyon. The proposed work addresses NPPC Program measures 7.5B.3 and 7.3B.5, and will be accomplished using established PIT tag methods, radio telemetry, and state-of-the-art habitat assessment techniques. Results will continue to be monitored and evaluated annually through real-time analyses, annual reports, peer-reviewed journal articles, and presentations.

Section 8. Project description

a. Technical and/or scientific background

Snake River fall chinook salmon have declined in abundance over the last three decades, and now managers are seeking methods to restore the population. Estimates of adult fish returning to the Snake River prior to 1957 number in the tens of thousands (Irving and Bjornn 1981), compared to a range of about 300-750 for 1991-1995 (Lavoy 1995). As a result, the stock was listed an "threatened" under the Endangered Species Act (USFWS 1988) in 1992 (NMFS 1992), and the Snake and Clearwater rivers were identified as critical habitat (NMFS 1995). In contrast, fall chinook salmon in the Hanford Reach of the Columbia River represent one of the few remaining healthy stocks in the Columbia River basin (Huntington et al. 1996; Dauble and Watson 1997), and the Hanford Reach serves as a comparison to the Hells Canyon Reach.

Supplementing the natural population of Snake River fall chinook salmon with hatchery fish has been proposed as an interim recovery measure, and will require thorough monitoring and evaluation. Supplementation was advocated by the Snake River Salmon Recovery Team (Bevan et al. 1994) and the NMFS (1995). The Recovery Team and the NMFS recommended outplanting Lyons Ferry Hatchery subyearling fall chinook salmon to mimic the life history of natural fall chinook salmon in the Snake River above Lower Granite Dam. Conversely, the Washington Department of Fisheries advocated outplanting yearling fall chinook salmon based on higher smolt-to-adult survival from on-station releases (Bugert et al. 1997). A compromise was reached among the federal agencies, state agencies, and the tribes which gave the yearling program first priority at Lyons Ferry Hatchery. An annual production goal of 900,000 yearlings was established, half of which were to be outplanted above Lower Granite Dam. Subyearlings have been made available for research to evaluate supplementation and survival since returning adults will produce progeny with a subyearling life history strategy.

Our study is designed to monitor and evaluate fall chinook salmon survival and supplementation in the Snake River. The use of supplementation is one means of increasing the number of fall chinook salmon, but will not necessarily equate with an increase in survival. For example, an average of 250,000 subyearling fall chinook salmon were released in the Snake River each year from 1978-1985 (Roseberg et al. 1992), but adult counts at Lower Granite Dam from 1981-1989 averaged only 667 $\pm$ 168 (Waples et al. 1991). It is therefore imperative to identify which variables and mechanisms influence survival for incorporation into tools fishery managers can use to improve supplementation.

Recently, Connor et al. (1998) showed that detection rates of wild, PIT-tagged subyearling fall chinook salmon at Lower Granite Dam—a relative measure of survival—was negatively related to temperature and positively related to flow. However, regressions included only four years of data, and additional data collection is necessary to confirm these relations. PIT-tagging efforts on wild fish by this project compliment the PIT tag/survival work currently being conducted by BPA Project 9302900 on hatchery fall chinook salmon (Smith et al. 1996). Survival estimation has not been done to date on Hanford Reach fall chinook salmon using rigorous statistical techniques such as those described by Smith et al. (1994) and Burnham et al. (1987). Our proposed survival work in the Hanford Reach will allow comparisons to Hells Canyon survival, and will provide an analysis to determine variables associated with high survival.

Other mechanisms that may influence survival such as predation (Tabor et al. 1993) and growth will be evaluated for both hatchery and wild subyearling fall chinook salmon. This stems from the observation made by Winton and Hilborn (1994) that one of the major weaknesses of past supplementation projects has been the lack of information compiled on the interactions between hatchery and natural fish.

This study will both directly and indirectly increase the number of fall chinook salmon in the Snake River basin. Direct increases in the number of hatchery juveniles out planted should produce an increase in the number of returning adults. If these adults are allowed to spawn naturally, then an increase in the natural population of fall chinook salmon should be realized. Indirect increases in the number of naturally produced fish will come through knowledge gained from this study which fishery managers can use to optimize survival and therefore increase the number of Snake River fall chinook salmon.

b. Rationale and significance to Regional Programs

The NPPC has established a policy to "...support and rebuild native species in native habitats, where feasible", in Program measure 2.2A. This goal can not be met, however, unless managers have a clear understanding of the factors that either limit fall chinook populations, or contribute to their health. This study has provided, and will continue to provide, information on ESA listed Snake River fall chinook salmon by addressing Program measure 7.5B.3 "Continue to fund basic life history studies for Snake River fall chinook salmon," which should, "identify the range, limiting factors, effects of flow, temperature, spawning and rearing habitat, and migratory behavior." In addition, this study also attempts to compare and contrast the dwindling Snake River population to that of the healthy Hanford Reach population. By doing so, we will be able to identify factors that mangers can use to recover Snake River fall chinook salmon, while promoting the continued health of the Hanford population. The ISAB recognized the importance of the Hanford Reach fall chinook population in a recent report to the NPPC (1998; ISAB report 98-5) by stating:

> "Over the last two decades, Hanford Reach fall chinook have continued to be productive, while other stocks have declined. Our continuing interest and concern for that particular stock of fish arises precisely because it is a relatively healthy stock. It deserves our attention as we attempt to identify and measure the factors that are responsible for its continuing productivity, so that these favorable elements might be extended to other stocks. Furthermore, we believe the productivity of the Hanford stock can be improved."

Under Objective 1, we will continue to produce survival estimates and in-season run-timing forecasts for juvenile fall chinook salmon in the Snake River, as we have in the past. Fishery managers have used this information in making flow augmentation decisions under Program measure 5.2B and 5.4B (Summer Migrants), which call for providing flow for juvenile fall chinook salmon. This has been an important aspect of our past work, and the resulting information has been relied heavily upon in preparation of recovery planning documents such as the Snake River Salmon Recovery Plan (Bevan et al. 1994). Objective 2 deals with residualism and is nearly complete.

Objectives 3 and 4 address Program measure 7.5B.1, "develop an experimental design for implementing, monitoring, and evaluating supplementation...for Snake River fall chinook." Results of our previous work were relied upon heavily by fishery managers when selecting the locations of supplementation acclimation facilities upstream of Lower Granite Dam. Our research will produce specific, relevant information that can be used by decision makers, and will include the influence of fish age, size, release site, release timing, and acclimation on yearling and subyearling fall chinook salmon survival through the lower Snake River. Our survival estimates will be useful in evaluating, "...flow augmentation during downstream migration", as called for in the SRSRP measure 2.1.d.3.

Objective 5 provides information on mechanisms that influence the survival of Snake River fall chinook salmon, and falls under Program measure 7.5B.3, but also relates to evaluating supplementation (Program measure 7.5B.1). The survival advantage associated with fast growth can be framed against risk from predation to model survival probability under different growth/predation scenarios for both hatchery and wild fish. The study task under this objective that assesses predation on juvenile fall chinook salmon falls under Program measure 5.7 and SRSRP measure 2.8.b.2, which recognizes the need for information on the interactions between juvenile salmonids and their predators.

Objective 6 addresses Program measure 5.0F, which states that research examining the relationships between flow, velocity, and fish survival should receive the highest priority. Estimating survival of Hanford Reach fall chinook would provide a comparison to that estimated for wild (this project) and hatchery (BPA project 9302900) Snake River fall chinook salmon. The recent addition of a PIT-tag interrogation site at John Day Dam will allow us to estimate survival to both McNary and John Day dams. This work should provide information that can be used by the PATH fall chinook workgroup.

Objective 7 pertains to Program measures 7.1A.1 and 7.6A.2 which relates to salmon habitat, and maintaining and improving habitat quantity and productivity. This objective will quantify the amount of suitable rearing habitat in both the Hells Canyon and Hanford reaches, and using digital elevation maps and habitat model will predict changes in habitat quantity and quality as flows change. This is especially critical in the Hanford Reach where power peaking at Priest Rapids dam has dramatic effects on juvenile chinook rearing habitat and stranding downstream. This objective complements the stranding evaluation of BPA Project 9701400 by examining the effects of water level fluctuations on rearing habitat, and BPA Project 9800401 in that it adds to our knowledge base of habitat processes.

c. Relationships to other projects

The supplementation portion of this project has been a collaborative effort between the U.S. Geological Survey, U.S. Fish and Wildlife Service (study cooperators), National Marine Fisheries Service (Project 9402900), Nez Perce Tribe of Idaho (Project 9403400), and Washington Department of Fish and Wildlife (WDFW). Collaboration is necessary to maximize the use of research fish, which are in short supply, so each project can accomplish its objectives, avoid duplication of effort, and minimize project costs. Specific areas of collaboration include joint efforts to PIT tag and transport hatchery fish to release sites, collection and sharing of recapture information, and the calculation of survival estimates.

Habitat assessment techniques described in Objective 7 represent a cooperative effort with WDFW, which is evaluating Hanford stranding under Project 9701400. Specific areas of cooperation involve sharing the cost of a bathymetric survey, which will aid in identifying rearing habitats and stranding sites in the Hanford Reach. This project also provided technical assistance to WDFW in conducting surveys of stranding and entrapment sites. Survival tasks described in Objective 6 will also need to be coordinated with WDFW PIT tagging efforts in the Hanford Reach (Project 8712700) in order to avoid duplication of effort and increase the usefulness of the data to both projects.

Technical assistance will be provided to USFWS under Project 9105 (Fall chinook spawning and rearing below Bonneville Dam - a new project in FY99) to input spawning and rearing habitat information into a Geographic Information System (GIS). Our expertise gained from past work using GIS to map spawning sites in Hells Canyon and rearing sites in Hells Canyon and the Hanford Reach should be a benefit to Project 9105.

Since this study involves natural Snake River fall chinook salmon, which is an ESA-listed stock, we have obtained the necessary state and federal permits to proceed with the project.

d. Project history (for ongoing projects)

This project has set a standard for cooperation between the NPT, WDFW, NMFS, Idaho Power Company, USFS, COE, USFWS, and USGS. Through cooperative research, it produced much of the empirical data on natural Snake River fall chinook salmon used for recovery planning. The results of this project have been used in the decision-making process to provide summer flows for subyearling chinook salmon in the lower Snake River. In its early phase (i.e. 1991 to 1995), this project produced accurate redd surveys, an estimate of spawning habitat carrying capacity for the Snake River Salmon Recovery Plan, a redd census technique in accord with the recovery plan to measure adult escapement to the spawning grounds, and a model to show the effects of Hells Canyon Complex flows on fall chinook salmon spawning habitat. This information has been used to provide minimum flows during adult spawning, egg incubation, and emergence in the Hells Canyon Reach. In addition, unprecedented genetic data has been collected on natural Snake River fall chinook salmon confirming the uniqueness of this stock. Documentation of the early life history, physiology, and habitat requirements of fall chinook salmon and models to relate juvenile emigration rate to water temperature and flow have been produced as well. Our laboratory data suggest a link between water velocity and migratory behavior, and has shown that factors such as fish size and water temperature are important to subyearling chinook emigration rate and survival. Our survival work has shown that fish released earlier in the season survive at a higher rate and larger fish survive better than smaller fish. This project’s radio telemetry work has provided information on intra-reservoir migration rates, areas of delay, and forebay behaviors which could not be obtained from PIT-tag data.

This project produced technical reports for BPA for the years 1991, 1992, 1993, 1994, 1995, and 1996-97 entitled, “Identification of the spawning, rearing, and migratory requirements of fall chinook salmon in the Columbia River basin.” This project has also summarized research results in Project 9302900’s 1995 and 1996 annual reports to BPA entitled, “Fall chinook salmon survival and supplementation studies in the Snake River and Lower Snake River Reservoirs.”

This project has participated in authoring the following manuscripts for peer review publication. Some of these represent collaborative efforts between this project and other researchers studying fall chinook salmon:

Connor, W.P., H.L. Burge, and D.H. Bennett. 1998. Detection of PIT-tagged subyearling chinook salmon at a Snake River dam: Implications for summer flow augmentation. North American Journal of Fisheries Management 18:530-536.

Dauble, D.D., R.L. Johnson, and **A.P. Garcia**. In Press. Fall chinook salmon spawning downstream of lower Snake River hydroelectric projects. Transactions of the American Fisheries Society.

P.A. Groves, and **A.P. Garcia**. In Press. Two carriers used to suspend an underwater video camera from a boat. North American Journal of Fisheries Management.

Marshall, A.R., H.L. Blankenship, and **W.P. Connor**. In Review. Identifying genetic race of Snake River juvenile chinook salmon and genetic characterization of the Snake River natural fall race population. Transactions of the American Fisheries Society.

Venditti, D.A., D.W. Rondorf, and J. Kraut. In Review. Migratory behavior and forebay delay of radio-tagged juvenile fall chinook salmon in a lower Snake River impoundment. North American Journal of Fisheries Management.

Tiffan, K.F., D.W. Rondorf, and P.G. Wagner. In Review. Physiological development and migratory behavior of subyearling fall chinook salmon in the Columbia River. North American Journal of Fisheries Management.

This project has been ongoing since 1991, and has received cumulative funds of 7.5 million dollars to date.

e. Proposal objectives

1) Determine the effects of rearing area, flow, and temperature on natural fall chinook salmon survival and migration timing to the tail race of Lower Granite Dam.
Null Hypothesis: Differences in rearing area, flow and temperature do not influence the survival of natural fall chinook salmon to Lower Granite Dam.
Assumptions: 1) Snake River fish spawned above the confluence of the Salmon River may survive better because water temperatures are warmer during egg incubation and produce earlier emergence. 2) Early emerging fish will become migrants earlier and be able to take advantage of higher flows and cooler water temperatures and thus have higher survival than later emerging fish that migrate under lower flows and higher temperatures.
Outcomes: Identification of life history traits that promote high smolt survival that can be used to assist the monitoring and evaluation of recovery strategies.

2) Investigate the occurrence of autumn subyearling and spring yearling emigration in Snake River fall chinook salmon populations. **This objective has been completed except for analysis and manuscript preparation.**
Outcome: Identification of the degree to which residualism may affect the accuracy of survival estimates, and to assess whether or not river reaches that are too cold to produce subyearling smolts have the potential to produce yearling smolts.

3) Evaluate the effect of fish size at release and environmental attributes on survival of Lyons Ferry subyearling fall chinook salmon. **This objective has been completed except for analysis and manuscript preparation.**
Null Hypothesis: Large and small hatchery fall chinook salmon have equal survival.
Assumptions: 1) Larger fish will have higher survival than smaller fish. 2) Lyons Ferry fall chinook salmon will be suitable surrogates for natural fish.

Outcome: Recommended size for releasing Lyons Ferry subyearling fall chinook salmon from the hatchery or for supplementation to ensure high survival.

4) Determine habitat use and migratory behavior of hatchery and natural fall chinook salmon in the Snake River.
Null Hypotheses: 1) Habitat use does not differ between hatchery and natural fall chinook salmon. 2) Water velocity and temperature do not influence the migration routes, migration rates, and thermal exposure in lower Snake River reservoirs.
Assumption: Adequate numbers of hatchery and natural fall chinook salmon will be captured in nearshore habitats to allow for an adequate statistical analysis.
Outcome: Identification of the amount of rearing habitat overlap that exists between hatchery and natural fall chinook salmon. Detailed information on migratory behavior within a reservoir that cannot be obtained using PIT tags.

5) Assess the relationship between growth rate and predation risk for hatchery treatment groups and natural fall chinook salmon. **The predation portion of this objective has been completed except for analysis and manuscript preparation.**
Null Hypothesis: Differences in growth rates and levels of predation in nearshore rearing areas do not affect survival of hatchery and natural fall chinook salmon.
Assumption: 1) Different growth rates and levels of predation risk do exist in populations of rearing fall chinook salmon. 2) Fish with faster growth will outgrow predators more quickly, reducing the time they are vulnerable to predation, and thereby increasing their survival.
Outcomes: 1) Quantification of the extent of smallmouth bass predation on juvenile fall chinook salmon in the Hells Canyon Reach. 2) Prey size selectivity by predators. 3) Determination of factors that produce the highest growth rates, and hence the lowest predation risk.

6) Determine the effect of seaward migration timing on natural Hanford Reach fall chinook salmon survival to the McNary and John Day dam tailraces, and compare findings to those for the Snake River from Objective 1.
Null Hypotheses: 1) There are no differences in survival between Hanford Reach fish released early in the season and those released later in the season. 2) There are no differences in early life history timing and survival between Hanford Reach and Snake River fall chinook salmon.
Assumptions: 1) Early migrants have higher survival than later migrants because they migrate in higher flows and cooler temperatures. 2) Fry emergence, rearing, and seaward migration will be earlier for Snake River fish because the Snake River is warmer. However, survival to the first dam encountered by fish will be higher for Hanford Reach fish because of less adverse migration conditions in the Columbia River.
Outcomes: Survival estimates of fish released at different times during the rearing season, and identification of environmental conditions associated with high survival. Comparison of survival of fall chinook in the Hanford Reach and the Snake River.

7) Determine the effects of flow fluctuations on the quantity and quality of juvenile fall chinook rearing habitat in the Hanford and Hells Canyon reaches.
Null Hypothesis: The quantity and quality of rearing habitat does not change as water levels fluctuate.
Assumption: a) The amount of available rearing habitat and productive capacity is determined by water elevation in a river channel. b) The productivity of rearing habitats in free-flowing river reaches can be influenced on a yearly (e.g. high vs. low flow years as determined by climate) and a daily (e.g. variation in flow due to hydroelectric operations) basis. c) Stranding and entrapment of fish in rearing habitats is a difficult problem to solve in a system that needs to maximize hydropower flexibility and minimize impacts to fish.
Outcome: a) A GIS-based model that will predict habitat changes concomitant with changes in both yearly and daily flow fluctuations.

f. Methods

The scope of this work covers the freshwater life cycle of fall chinook salmon from fry emergence, nearshore rearing, and seaward migration, and includes work on both natural and hatcheryreared fish. The project focuses research efforts in the Snake River because of the need for information to aid in recovery of its fall chinook stock, and also in the Hanford Reach because its viable fall chinook population is useful for comparative purposes. The analyses will allow us to identify the attributes of the Hanford Reach population that contribute to its healthy status as compared to the depressed Snake River population.

Objective 1. Determine the effects of early life history on natural fall chinook salmon survival and migration timing to the tail race of Lower Granite Dam.
<u>Task a.</u> Capture and PIT tag natural fall chinook salmon rearing in different areas of Hells Canyon.
Methods:. There are three cohorts of subyearlings which rear in the Snake River based on adult spawning locations. In theory, each of these cohorts emerge, rear, and migrate on different time schedules based on water temperatures during egg incubation and emergence. We will collect fish from each cohort and PIT tag all fish > 60 mm. A target of 3,000 fish (i.e., 1,000 from each cohort) will be PIT tagged each year to obtain an optimum number of detections at Snake River dams.
<u>Task b.</u> Provide annual run-timing estimates for juvenile Snake River fall chinook for the Smolt Monitoring Program and Fish Passage Advisory Committee and summer flow augmentation decisions.
Methods: Use the PIT-tag data and analytical technique developed by Connor et al. (In Preparation) to forecast dates of passage at Lower Granite Dam. This information will be provided to the Technical Management Team in real time (as it was from 1991-1998) to help them time the release of water for summer flow augmentation.
<u>Task c.</u> Test for differences in detection patterns at Lower Granite Dam of fish tagged in different rearing areas.
Methods: Calculate and compare the emergence dates for each cohort. Calculate abundance estimates for rearing fish using a Jolly-Seber mark-recapture model for open populations and compare the temporal trends of these estimates among the cohorts. Compile a recapture database of fish detected at Lower Granite Dam and compare passage distributions of the three cohorts using a Kolomogorov-Smirnov test.
<u>Task d.</u> Determine if survival of release groups is related to rearing area, flow, temperature, and travel time.
Methods: Calculate the survival of each cohort of natural fall chinook salmon passing lower Snake River dams. Use ANOVA, or the nonparametric analog, to compare survival of cohorts. We will test for a cause and effect relation between survival and flow, temperature, and turbidity using multiple or logistic regression

Objective 2. Investigate the occurrence of yearling emigration (i.e., residualism) in Snake River fall chinook salmon. **This objective has been completed except for analysis and manuscript preparation.**
<u>Task a.</u> Determine the prevalence of subyearling holdover using PIT tag detection data.
Methods: Compile a database of fall chinook salmon PIT tagged as subyearlings and detected in the spring as yearlings. A critical uncertainty is that fish collection at dams ceases in November and does not begin again until the following spring. This means that an unknown number of late migrants may have the opportunity to outmigrate without being detected during this period. This fact may reduce the accuracy of estimates of prevalence of late autumn and winter migration. Notably, ongoing analyses indicate that only a small percentage of emigrating PIT-tagged fall chinook salmon go undetected.
<u>Task b.</u> Correlate the prevalence of holdover with environmental and genetic data.
Methods: Use correlation analysis to examine the relations between holdover behavior and the run of fish tagged (i.e., fall vs. spring; some subyearling spring race fish are tagged each year), tagging location, tagging date, fork length, flow, and temperature. Possible results are 1) late migrants are actually subyearling spring chinook salmon, and 2) fish tagged late in the season migrate under poor environmental conditions, which suppress smoltification and willingness to migrate.
<u>Task c.</u> Determine the feasibility of estimating the origin of holdover fish using genetic and scale pattern data.
Methods: Collect scales and DNA samples from holdover fish. Group fish by rearing area and race. Digitize scale patterns and use discriminant analysis to determine if scale pattern can be used to determine if fish originate from the Snake River. Fish from the Grand Ronde and Clearwater river, which may experience cooler rearing conditions, may be late migrants and their scales may reflect their rearing environment.

Objective 3. Evaluate the effect of fish size at release and environmental attributes on survival of Lyons Ferry subyearling fall chinook salmon. **This objective has been completed except for analysis and manuscript preparation.**

Task a. Obtain and release sufficient numbers of hatchery fall chinook salmon to determine the effects of size at release on survival through lower Snake River dams.

Methods: Release 10,000 acclimated (30 days) hatchery yearling with 10,000 non-acclimated 95-mm hatchery subyearlings in April at Pittsburg Landing in Hells Canyon. Release 20,000 subyearlings at Pittsburg Landing in June including fork length groups averaging 75 mm, 85 mm, and 95 mm. All fish will be PIT tagged and sample sizes are based on previous work and are large enough to calculate precise survival estimates at Lower Granite, Little Goose, and Lower Monumental dams.

Task b. Estimate survival of each hatchery release group using the SURPH model (Smith et al. 1994)

Methods: Coordinate this activity with National Marine Fisheries Service.

Task c. Use multivariate statistics and analysis of variance techniques to determine if differences in survival are related to fish size, temperature, flow, and travel times.

Methods: Use the statistical test mentioned above to look at the effects of acclimation, size at release, travel time, flow, and temperature on survival of hatchery release groups. Results from 1997 and 1998 indicate that the survival difference between acclimated hatchery yearling and non-acclimated subyearling fall chinook salmon is related to fork length at release and date of release. Releasing 95-mm long subyearlings in late spring may result in smolt survival equal to that of yearlings released in April.

Objective 4. Determine habitat use and migratory behavior of hatchery and natural fall chinook salmon in the Snake River.

Task a. Determine post-release dispersal patterns of hatchery fish in Hells Canyon.

Methods: Recapture hatchery fish in rearing areas of Hells Canyon by beach seining weekly. **Complete except for analysis and manuscript preparation.**

Task b. Describe post-release habitat use by hatchery fish to determine the extent of hatchery-wild overlap in nearshore rearing areas.

Methods: Use point electrofishing to capture both hatchery and wild fall chinook salmon in rearing habitats that vary in depth, velocity, and substrate. Use principal components analysis and discriminant analysis to describe habitat use and overlap by both groups. **Complete except for analysis and manuscript preparation.** A critical uncertainty is the efficacy of the statistical analysis to produce meaningful results given the low sample sizes obtained during field sampling. In the event that results are inconclusive, a similar habitat analysis being conducted on Hanford Reach fall chinook salmon, by this project, should provide a surrogate model for use in completing this task.

Task c. Use radio telemetry to describe the migratory behavior and thermal history of active migrants in the lower Snake River.

Methods: Tag natural fall chinook salmon migrants at Lower Granite Dam with temperature-sensitive radio tags, and use mobile and fixed-site telemetry to subsequently detect fish in Little Goose Reservoir. Tag 3 groups of 7 fish each per week (N=21 fish/week) for 6 weeks in July and August. Obtain continuous coverage for 48-h periods on a subsample of fish using mobile tracking to obtain thermal histories. This was proven to be feasible in 1998. The use of temperature-sensitive tags is an innovative approach that allows the collection of geospatial data (location, latitude, longitude) as well as temperature data that fish are actually exposed to in addition to collecting location and migration rate information. Bathythermographs will also be deployed at fish locations to determine the temperature a fish is selecting versus the temperature range of the water column.

Objective 5. Assess the relationship between growth rate and predation risk for hatchery treatment groups and natural fall chinook salmon.

Task a. Modify and use an existing chinook salmon bioenergetics model to predict food consumption and growth of hatchery and wild fish in nearshore rearing areas.

Methods: Collect food habit information from both hatchery and wild juvenile fall chinook in rearing areas **(Completed)**. Modify parameters of a bioenergetics model for chinook salmon (Stewart and Ibarra 1991), and use it to predict consumption and growth of hatchery and wild fish under different supplementation scenarios. The expected result is that fish in rearing areas are feeding at maximum consumption rates, however, it is unknown whether high water temperatures are driving up metabolic costs to the point that fish health and survival may be compromised. The bioenergetic approach will allow us to explore these possibilities.

Task b. Determine the extent and size selectivity of predation by smallmouth bass on hatchery and wild subyearling fall chinook in the Hells Canyon Reach. **(Complete except for analysis.)**

Methods: Collect smallmouth bass in Hells Canyon by electrofishing, lavage their stomachs, and tag with floy tags for mark-recapture. Identify stomach contents (Hansel et al. 1988) to estimate the extent of predation of juvenile fall chinook salmon. Use mark-recapture techniques to determine the relative abundance of smallmouth bass in sampling reaches. Estimate the total number fall chinook lost to predation during the rearing and outmigration season. The expected result is that predation may be high after hatchery releases and near release sites (Shively et al. 1996). Whether a feeding response in smallmouth bass causes increased predation pressure on wild fall chinook is uncertain.

Task c. Use an individual-based modeling approach (Jager et al. 1993) to synthesize predation risk and growth advantage as it relates to survival, supplementation scenarios, and environmental conditions.

Methods: Input variables will include prey size, growth rates, prey density, predator density, water temperature, and predator-prey encounter probability. Outputs will likely be chinook losses to predation under different levels of initial densities, temperature and growth.

Objective 6. Determine the effect of seaward migration timing on natural Hanford Reach fall chinook salmon survival to the McNary and John Day dam tailraces, and compare findings to those for the Snake River from Objective 1. **(This is a multi-year objective)**

Task a. Capture and PIT tag natural fall chinook salmon rearing in the Hanford Reach.

Methods: We will collect subyearlings which rear in the Columbia River in the Hanford Reach above the head of McNary pool. Sampling will be done weekly from April to mid June, and all fish > 60 mm will be PIT tagged. A target of 1,250 will be PIT tagged each week, and tagging will be evenly distributed throughout the Reach. PIT tagging will be coordinated with WDFW PIT-tagging efforts in the Hanford Reach. One uncertainty is the possibility of tagging hatchery fall chinook after releases from Priest Rapids Hatchery. These releases usually begin in mid June, about the time of our last release. Based on our past experience, larger hatchery fish can usually be distinguished from the smaller wild fish. In addition, we may be able to time our last release to occur just prior to the first release from Priest Rapids.

Task b. Test for differences in seaward migration timing among weekly releases.

Methods: Compile a recapture database of fish detected at McNary Dam and compare the passage distributions among weekly releases using a Kolomogorov-Smirnov test.

Task c. Test for differences in survival to the tailrace of McNary and John Day dams among the weekly releases.

Methods: Use PIT-tag data to estimate survival using the SURPH model (Smith et al. 1994) and test for differences among groups using analysis of deviance.

Task d. Determine the relation between survival and flow, temperature, and turbidity.

Methods: Use ordinary least-squares regression or multiple regression to determine the effect of each variable on survival.

Task e. Test for differences in early life history (i.e., emergence timing, growth, and migration timing) and survival between Snake River and Hanford Reach fish.

Methods: Pool data by river to produce a data set for each river. Calculate and compare emergence dates, migration timing, passage distribution, and survival for fish from each river using ANOVA, or a nonparametric analog, after multiple years of replication has been obtained.

Objective 7. Determine the effects of flow fluctuations on the quantity and quality of juvenile fall chinook rearing habitat in the Hanford and Hells Canyon reaches. **(This is a multi-year objective)**

Task a. Produce a bathymetric map of rearing areas in the Hanford Reach and Hells Canyon.

Methods: Bathymetric maps (accuracy $\pm$ 15 cm) will be produced using the latest laser surveying technology (LIDAR) and put into a GIS. Through a cooperative and cost-sharing effort with BPA Project 9701400, our project took the lead in contracting a LIDAR survey of approximately 17 miles of the Hanford Reach in 1998. An additional survey will be needed to cover the rest of the reach that encompasses fall chinook rearing habitat. Idaho Power Company also competed a similar survey of the Hells Canyon Reach in 1998, which obviates our need to conduct a survey there.

Task b. Collect water velocity information for surveyed areas for use as a criterion to define quality rearing habitat, and for flow modeling.

Methods: Collect velocities across transects in the surveyed areas using an acoustic Doppler current profiler (ADCP), or obtain existing data from USFWS.
Task c. Choose a two-dimensional flow model that will predict water surface elevations given river discharge.
Methods: There are different hydraulic models that currently exist that should suit our application. A thorough review of the capabilities of different models is a necessary first step.
Task d. Synthesize the above information with variables that define quality juvenile fall chinook rearing habitats into a predictive model.
Methods: The hydraulic model and velocity information will allow us to overlay water surface elevations on our bathymetric map in our GIS. Using our GIS, we will then be able to delineate areas that contain suitable depth, slope, velocity, and substrate that define quality fall chinook habitat. We have already obtained this habitat information in previous year's work. Spatial analysis will allow us to quantify the amount of rearing habitat on reach-wide basis at a given flow. By modeling different river discharges, we will be able to see how the quantity of rearing habitat changes as discharge changes, which can be examined on an hourly, daily, yearly, etc., time step. Since this will be done for both the Hanford and Hells Canyon reaches, results can be compared to elucidate differences in productivity of the two systems.

g. Facilities and equipment

The Columbia River Research Laboratory is equipped with all of the resources necessary to carry out this project. Each person employed by this project has computer and the necessary software to complete data reduction, storage, and complex statistical analyses. In addition, we have a state-of-the-art GIS computer system and software at the lab. Our wet lab has been used for years to conduct experiments to meet project objectives. It is supplied with well water, an aeration system to provide air to each holding tank, complete photoperiod and temperature control, and we have a full-time wet lab supervisor who oversees and maintains the facility. As for field activities, this project has all the boats, vehicles, and capital equipment necessary to collect data for field-related tasks. Our radio telemetry activities use state-of-the-art miniature radio tags and digital receivers.

Our project cooperators (USFWS) are also equipped with the necessary office space, equipment, boats, vehicles, and personnel to accomplish project objectives.

h. Budget

The budget described in Part I Section 5 is a combined budget for USGS and our cooperators (U.S. Fish and Wildlife). The largest components of the budget are for personnel and benefits. This project has been studying fall chinook salmon for the last eight years, and its personnel have acquired considerable knowledge and expertise in this area. Consequently, we feel that our people and their experience with fall chinook are the most valuable assets to this project. Other items such as Supplies, Travel, Vehicles and Boats, and PIT tags will be split between USGS and USFWS and represent the cost of conducting research in both the Hells Canyon and Hanford reaches. The cost of the LIDAR survey of the Hanford Reach will be shared with BPA Project 97014 (Hanford Reach stranding evaluation). The figure provided represents USGS's portion.

Section 9. Key personnel

Project Manager:
Dennis W. Rondorf
Research Fisheries Biologist, 1 FTE

EDUCATION:
M.S. Oceanography and Limnology, University of Wisconsin, Madison, 1981
B.S. Wildlife Management, University of Minnesota, St. Paul, 1972

CURRENT EMPLOYMENT AND RESPONSIBILITIES:

D.W. Rondorf serves as a Research Fisheries Biologist and Section Leader for the Anadromous Fish Ecology section at the Columbia River Research Laboratory, Biological Resources Division, U.S. Geological Survey, Cook, Washington. Current areas of research include the behavior and ecology of Snake River wild and hatchery fall chinook salmon, the distribution of smolts and relation to gas supersaturation in the main stem Columbia River, and behavior of smolts to evaluate a prototype surface collector at Lower Granite Dam, Washington. In recent years, D.W. Rondorf has lead research teams using radio telemetry, geographic information systems (GIS), global positioning systems (GPS), remotely operated underwater vehicles (ROV), hydroacoustic fish stock assessment systems, and acoustic Doppler current profilers (ADCP) as research tools. Between 1979 and 1997, D.W. Rondorf was employed by the research division of the U.S. Fish and Wildlife Service and the National Biological Service to conduct research on juvenile salmon in the Columbia River basin.

Rondorf, D.W., K.F. Tiffan, W.P. Connor, and H.L. Burge, editors. 1998. Identification of the spawning, rearing, and migratory requirements of fall chinook salmon in the Columbia River basin. Annual Report to the Bonneville Power Administration, Portland, Oregon.

Adams, N.S., D.W. Rondorf, S.D. Evans, J.E. Kelley, and R.W. Perry. 1998. Effects of surgically and gastrically implanted radio transmitters on swimming performance and predator avoidance of juvenile chinook salmon. Canadian Journal of Fisheries and Aquatic Sciences 55:781-787.

Adams, N.S., D.W. Rondorf, S.D. Evans, and J. E. Kelley. 1998. Effects of surgically and gastrically implanted radio transmitters on growth and feeding behavior of juvenile chinook salmon. Transactions of the American Fisheries Society 127:128-136.

Parsley, M.J., D.W. Rondorf, and M.E. Hanks. 1998. Remote sensing of fish and their habitats. Proceedings of instream and environmental flows symposium-technology and policy issues. (*In Press*) North American Lake Management Society and others, Denver, Colorado.

Adams, N.S., D.W. Rondorf, E.E. Kofoot, M.J. Banach, and M.A. Tuell. 1997. Migrational characteristics of juvenile chinook salmon and steelhead in the forebay of Lower Granite Dam relative to the 1996 surface bypass collector tests. U. S. Army Corps of Engineers, Walla Walla, Washington.

Principal Investigator:
William P. Connor
Fisheries Biologist, 1 FTE

Education:
Master of Science—1988; Montana State University; degree in Fish and Wildlife Management
Bachelor of Science—1984; West Virginia University; degree in Fish and Wildlife Management

Employment:
1991 to Present—Fishery Biologist for the U.S. Fish and Wildlife Service. Conducting research on fall chinook salmon in the Snake and Clearwater rivers.

1987 to 1991—Fishery Research Biologist for the Nez Perce Tribe of Idaho. Conducted fall chinook salmon research in the Clearwater River.

Current Responsibilities:
Principle investigator for the U.S. Fish and Wildlife Service who are cooperators on this project. Responsible for oversight of Snake River fall chinook salmon redd surveys, juvenile seining and PIT tagging efforts, supplementation/survival releases and analysis, and emergence and outmigration forecasting.

Expertise:
William Connor has over 10 years as a fishery biologist focusing on Snake River fall chinook salmon research. He has been involved with all Snake River fall chinook salmon research conducted upstream of Lower Granite Dam since 1987. His research efforts provided fishery managers with new empirical information on Snake River fall chinook salmon redd surveys, spawning habitat availability, spawning habitat quality, early life history, travel time analyses, juvenile run timing predictions, survival, supplementation, and summer flow augmentation.

Work Products:
—Several journal manuscripts are in preparation including one published in the North American Journal of Fisheries Management.

> Connor, W. P., H. L. Burge, and D. H. Bennett. 1998. Detection of PIT-tagged subyearling chinook salmon at a Snake River dam: Implications for summer flow augmentation. North American Journal of Fisheries Management 18:530-536.

—Coauthored nine BPA annual reports
—Presented eight different papers at formal meetings with attendance > 100 persons

Principal Investigator:
Kenneth F. Tiffan
Research Fisheries Biologist, 1 FTE

Education:
Master of Science—1992; Colorado State University; degree in Fishery Biology
Bachelor of Science—1987; Colorado State University; degree in Fishery Biology
Employment:
1992 to Present—Research Fisheries Biologist for the Biological Resources Division (USGS). Conducting research on fall chinook salmon in the Snake and Columbia rivers.

Current Responsibilities:
Assistant project manager. Responsible for oversight of research conducted by BRD employees including radio telemetry, bioenergetics, habitat/GIS studies, and predation, and coordination of BRD and USFWS research. Responsible for editing annual project reports, budgeting, and obtaining necessary fish collection.

Expertise:
Kenneth Tiffan has over 6 years as a fishery biologist focusing on Snake and Columbia river fall chinook salmon research. He has been involved with this project since 1992 and has experience in fall chinook salmon physiology, field and laboratory investigations of migratory behavior, and habitat use. He has been instrumental in information transfer for this project by coordinating, authoring chapters, and editing annual project reports. His knowledge of political and administrative processes help keep these impediments from hindering project operations and accomplishments.

Work Products:
—Coauthored and edited five annual project reports.
—Two journal manuscripts are in preparation; one entitled "Physiological development and migratory behavior of subyearling fall chinook salmon in the Columbia River" is in review at the North American Journal of Fisheries Management, and the other entitled , "Morphological differences between emigrating spring and fall chinook salmon in the Snake River" is being prepared for submission to Transactions of the American Fisheries Society.
—Two informal presentations on fall chinook physiology have been given, one to the 18th annual Smolt Workshop in Corvallis, Oregon in 1995, and the other to the Fall Chinook Coordination Meeting in Lewiston, Idaho, also in 1995.
—A formal paper entitled "Osmoregulatory and ATPase development in subyearling fall chinook salmon in the Columbia River" was presented at the International Congress on the Biology of Fishes in San Francisco, California in 1996.

Section 10. Information/technology transfer

Information obtained will be disseminated in annual technical project reports, peer-review publications, presentations to work groups such as FPAC and PATH, and at professional meetings. Geospatial data generated under habitat-related tasks will be made available electronically as metadata via the National Geospatial Data Clearinghouse internet website. Our estimates of natural fall chinook salmon emergence dates and run size and timing will be made available to the Fish Passage Center annually for their oversight of smolt monitoring activities at Snake and Columbia river dams, and to fishery managers for summer flow augmentation.

Congratulations!